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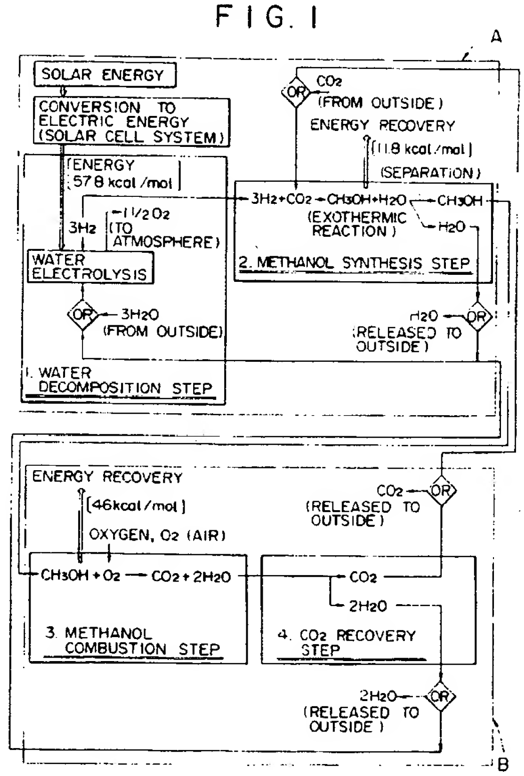
(54) **Method of supplying energy through medium of methanol.**

(57) A method of supplying energy through the medium of methanol which comprises electrolysis of water (1), synthesis of methanol (2) from recovered carbon dioxide and hydrogen obtained in the preceding step, methanol combustion (3) for the production of energy, and recovery of carbon dioxide (4) that has resulted from the combustion of methanol. Alternatively, the step of electrolysis of water (1) is followed by synthesis of methanol (2) from hydrogen obtained in the preceding step, recovered carbon dioxide, and recovered hydrogen, methanol decomposition (3) by given energy for separation of methanol into carbon monoxide and hydrogen, carbon monoxide combustion (4) for burning carbon monoxide to give energy and recover the resulting carbon dioxide, and recycling of the hydrogen that has resulted from the methanol decomposition to the process of methanol synthesis.

FIG. I



FIELD OF THE INVENTION AND RELATED ART STATEMENT

The present invention relates to a method of supplying energy through the medium of methanol, and more particularly to a method of energy supply which theoretically involves no energy attenuation during transmission or storage and is applicable, above all, to long-distance transmission or longterm storage of energy.

As is commonly known, the energy that the human being consumes today is mostly derived from fossil fuels such as petroleum.

However, petroleum that makes up a large percentage of fossil fuel supply is limited in reserve.

In addition, various exhaust and other emissions resulting from the use of fossil fuels have increasingly impaired the global environment and life on the earth including the humans. It has been warned that even though. the fossil energy reserves do not pose a problem, irreparable environmental disruption will result if things are left as they are.

In recent years, among the exhaust emissions, carbon dioxide has become largely responsible for the phenomenon of global warming since far more carbon dioxide is being produced than is recovered by nature. There is a strong demand, therefore, for the reduction of its overall production.

Investigations have thus far been made on the replacement of fossil fuels by other energy sources. Utilization of powers such as of solar heat, winds, waves, temperature difference between surface and deep-sea waters, and also of geothermal and nuclear powers has been studied and partly carried into practice.

Harnessing the energies from these sources for industrial and other uses, however, requires large-scale installations exclusively designed for the particular purposes. The sites where such exclusive installations can be built are restricted to specific locations, usually remote from the energy-consuming urban areas.

If energy were transmitted from the site of such an exclusive installation all the way to a consuming area, as converted to electric energy as is customary in the art, the cost of transmission facilities and the energy loss involved would be quite enormous.

Transmission of energy in the form of light or heat is out of question because the energy would diminish before being transferred a distance of only several kilometers.

Assuming that a solar heat power plant was built somewhere in a vast desert or highland, e.g., the Sahara, Arabian, or Australian desert, or the Tibet highland, it would be practically impossible in Japan to utilize the electric energy from that plants Wherever located, the plant would be tens of thousands of kilometers away from this country, and the transmission line from the plant would have to cross an ocean or oceans.

In municipal and suburban areas electricity is available readily and relatively inexpensively at a late-night discount. Nevertheless, the recipients of the service are limited, and more effective utilization of the midnight power supply is desired.

OBJECT AND SUMMARY OF THE INVENTION

The present invention has been made in view of the afore-described circumstances surrounding energy supply. It is an object of the present invention to supply energies that are inexhaustibly obtained in certain regions or by installations as, for example, solar heat, wind, wave, seawater temperature differential, geothermal, and nuclear powers, and also the electric power available at low prices in the depth of night, efficiently and as desired to energy-consuming areas or during heavy demand periods.

Another object is to maintain the material balance involved within a practically closed system so as to avoid an increase in the carbon dioxide content of the atmosphere that has deleterious effects upon the global environment.

For the purposes of describing the invention any of the energies obtained in the certain regions or during specific periods is called "given energy".

Thus, the invention provides a method of supplying energy through the medium of methanol which is used as energy transportation and storage means, with the material balance maintained within a practically closed system to avoid unfavorable effects, e.g., upon the environment, which method comprises the steps of: water decomposition in which water is decomposed into hydrogen and oxygen by electric energy obtained from a given energy source; methanol synthesis in which methanol is synthesized from carbon dioxide recovered in a subsequent carbon dioxide recovery step and from the hydrogen obtained in the water decomposition step and then the synthesized methanol is separated from secondarily produced water; methanol combustion in which the methanol that has been synthesized in the methanol synthesis step is burned to produce available energy; and carbon dioxide recovery in which carbon dioxide and water that have resulted from the methanol combustion step are separately recovered. *

According to this method of energy supply, given energy is converted to electric energy and used in electrolyzing water to produce hydrogen, and the resulting hydrogen is combined with carbon dioxide that has been recovered in a carbon dioxide recovery step to synthesize methanol, with concomitantly produced thermal energy being recovered when necessary.

The synthesized methanol, a chemical substance that theoretically undergoes no energy attenu-

In the section A solar energy is converted by a solar cell system to electric energy, which in turn is supplied to a water decomposition step 1. The quantity of energy used in the step, e.g., is 57.8 kcal/mol.

The water decomposition step I gives oxygen ($1\frac{1}{2}O2$), which is released to the atmosphere, and hydrogen ($3H_2$), which is used, together with carbon dioxide to be mentioned later, in a methanol synthesis step 2.

The reaction formula of the methanol synthesis is $3H_2+CO_2 \rightarrow CH_3OH+H_2O$. This reaction is exothermic and produces 11.8 kcal/mol of energy, which is recovered.

Methanol synthesized in the methanol synthesis step and water as a by-product are separated. Water is either discharged from the system or is recycled to the above-mentioned water electrolysis step 1.

The synthesized methanol from the synthesis step 2 is transported to the section B, where it is burned in a methanol combustion step 3. Here the reaction formula is $CH_3OH+O_2 \rightarrow CO_2+2H_2O$. The thermal energy thus generated is recovered, at the rate of 46 kcal/mol. This energy is consumed in industrial and other applications.

Thus, the energy used for the electrolysis of water is almost completely recovered in the steps of methanol synthesis and combustion, and the recovered energy is utilized for various purposes.

The carbon dioxide and water that have resulted from the combustion of methanol are separated by a carbon dioxide recovery step 4, and water is discharged from the system. Even when both water and carbon dioxide are released to the atmosphere, they are eventually recovered from nature and elsewhere separately for reuse, in what may practically be called a closed system.

It is further possible to transport the hydrogen obtained in the water decomposition step 1 to the section B, carry out the methanol synthesis step 2 in the same section, recover the resulting thermal energy, and utilize it, together with the energy that the methanol combustion step 3 yields, in industrial and other activities.

(Example 2)

Another example of the invention will be described below in conjunction with Fig. 2.

In this example the late-night power supply that is obtainable easily and relatively inexpensively in municipal and suburban areas is used as the energy source for the water decomposition step 1.

The oxygen ($\frac{1}{2}O_2$) that has resulted from the water decomposition step 1 is released to the atmosphere, while the hydrogen (H_2) from the same step is temporarily kept in storage. The latter is used, during the high demand period such as daytime when the energy consumption is large, for the methanol synthesis, along with the carbon dioxide to be described later, in the methanol synthesis step 2. The thermal energy produced by the methanol synthesis is recovered and allotted to industrial and other applications.

The methanol that has been synthesized in the methanol synthesis step 2 and the water produced secondarily are then separated. The water is discharged trom the system or is recycled to the water electrolysis step 1. The methanol is sent to the methanol decomposition step 3, where it is separated into carbon monoxide and hydrogen by dint of the energy derived from the late-night power. The reaction that takes place in the step 3 is endothermic. The hydrogen thus obtained is transferred to the methanol synthesis step 2 for use in the synthesis of methanol.

The carbon monoxide is once stored and, when energy consumption increases due to heavy power demand, e.g., in the daytime, it is pumped out and burned to yield adequate thermal energy, which is recovered for use in industrial and other activities. The carbon dioxide that has resulted from the combustion of carbon monoxide is used in methanol synthesis in the methanol synthesis step 2.

The energy balances in the two examples thus far described are given in Figs. 1 and 2.

Claims

1. A method of supplying energy through the medium of methanol which is used as energy transportation and storage means with the material balance maintained within a practically closed system, which method comprises the steps of: water decomposition in which water is decomposed into hydrogen and oxygen by electric energy obtained from a given energy source; methanol synthesis in which methanol is synthesized from carbon dioxide recovered in a subsequent carbon dioxide recovery step and from the hydrogen obtained in the water decomposition step and then the synthesized methanol is separated from secondarily produced water; methanol combustion in which the methanol that has been synthesized in the methanol synthesis step is burned to give energy; and carbon dioxide recovery in which carbon dioxide and water that have resulted from the methanol combustion step are separately recovered.

2. A method of supplying energy through the medium of methanol which is used as energy transportation and storage means with the material balance maintained within a practically closed system, which method comprises the steps of: water decomposition in which water is decomposed into hydrogen and oxygen by electric energy obtained from a given energy source; me-

ation and is a liquid convenient for transportation and storage, is shipped to an energy-consuming area or stored for a given period of time and then burned in the methanol combustion step for the recovery of its energy.

The carbon dioxide that has resulted from the combustion is recovered in the carbon dioxide recovery step and utilized in the synthesis of methanol as described above.

The water produced by the synthesis and burning of methanol is recycled to the electrolysis step for water decomposition.

Even if the water is drained off instead of being reused for electrolysis, it would be possible to supply water separately from somewhere else, e.g., the region where the given energy is available, and the system would practically remain closed.

The same is true of the carbon dioxide that results from the combustion of methanol and that which is used in the synthesis of methanol. They can be likewise procured from the region where the given energy is available. The energy supply method of the invention, therefore, can be carried in practice within a practically closed system, excluding the use and recovery of the given energy that are performed separately, without causing an increase in the overall carbon dioxide concentration in the atmosphere.

The invention further provides a method of supplying energy through the medium of methanol which comprises the steps of: water decomposition in which water is decomposed into hydrogen and oxygen by electric energy obtained from a given energy source; methanol synthesis in which methanol is synthesized from carbon dioxide recovered in a subsequent carbon monoxide combustion step and from the hydrogen obtained in the water decomposition step and also in a subsequent methanol decomposition step and then the synthesized methanol is separated from secondarily produced water; methanol decomposition in which the methanol that has been synthesized in the methanol synthesis step is decomposed into carbon monoxide and hydrogen by the energy from a given energy source; and carbon monoxide combustion in which the carbon monoxide that has been obtained in the methanol decomposition step is burned to produce available energy, while the carbon dioxide thereby produced is recovered.

In accordance with this energy supply method, given energy is converted to electric energy for use in electrolysis of water to give hydrogen, and carbon dioxide recovered by combustion of carbon monoxide, hydrogen obtained by decomposition of water, and hydrogen obtained by decomposition of methanol are combined to synthesize methanol, the thermal energy generated then being recovered when necessary.

The synthesized methanol is decomposed in the methanol decomposition step into carbon monoxide and hydrogen using the given energy, and the carbon monoxide is combusted to recover its energy.

The combustion also produces carbon dioxide, which is recovered and is used along with hydrogen for the synthesis of methanol. This energy supply method is performed like the first method in a practically closed system.

The energy supply method of the invention utilizes energy sources abundantly available in specific regions, such as solar heat, wind, wave, and seawater temperature differential, geothermal, and nuclear powers, and also the electric power available at low prices in the depth of night even in urban and suburban areas. The method uses such energy in electrolysis of water and synthesis of methanol. Consequently, the energy is converted to methanol, hydrogen, or other form which theoretically undergoes no attenuation, and long-distance transportation and storage without energy loss is realized. The synthesized methanol is burned or is decomposed while carbon monoxide is burned and the resulting thermal energy is recovered for use in industrial and other activities in an energy-consuming area or during an energy-consuming period.

In this way inexhaustible energy resources remote from the consuming areas can be effectively exploited. In the neighboring regions surrounding the consuming centers any surplus of electric energy is stored and is released when the system load becomes heavy. These features offer advantages including levelling of the operation of different power plants involved.

Moreover, because the process operates practically in a closed system except for the use and recovery of the energy, it can cause no such global environmental disruption as do the conventional methods that depend on fossil fuels for energy supply.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic diagram illustrating a working example (Example 1) of the present invention; and

Fig. 2 is a schematic diagram illustrating another example (Example 2) of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

(Example 1)

An example of the invention will now be described with reference to Fig. 1. A section A represents a region with abundant energy supply, in this case an African desert region prolific in solar energy and having a large enough land to set up installations for energy conversion such as solar cell arrays.

Another section B represents an energy-consuming region, e.g., Japan.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 92 40 2463

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)

Y	EP-A-0 413 199 (SIEMENS AG)
	* abstract *
	* column 1, paragraph 1 *
	* column 1, line 25 - column 2, line 23 *
	* column 9, line 39 - column 10, line 16 *
	* figure 2 *
	--- 	
		1	F24J1/02
			// F01K23/06
			// F02C3/28
			// F24J2/00

Y	US-A-5 001 902 (PAUL W.GARBO) * abstract * * figure * * column 1, line 6 - line 8; figure * * column 1, line 48 - line 68; figure * * column 2, line 5 - line 67 * * column 3, line 30 - column 6, line 25 * ---	1	
A	DE-A-2 425 939 (METALLGESELLSCHAFT AG) * page 1, column 1 - column 3 * * page 2, column 4 - page 4, column 2 * * figure * ---	2	
A	DE-A-2 447 913 (RHEINISCHE BRAUNKOHLENWERKE AG) * page 1, column 3 * * page 2, column 2 - page 3, line 8 * * figure * -----	2	TECHNICAL FIELDS SEARCHED (Int. Cl.5) F24J F02C F01K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 DECEMBER 1992	SIEM T.D.

CATEGORY OF CITED DOCUMENTS

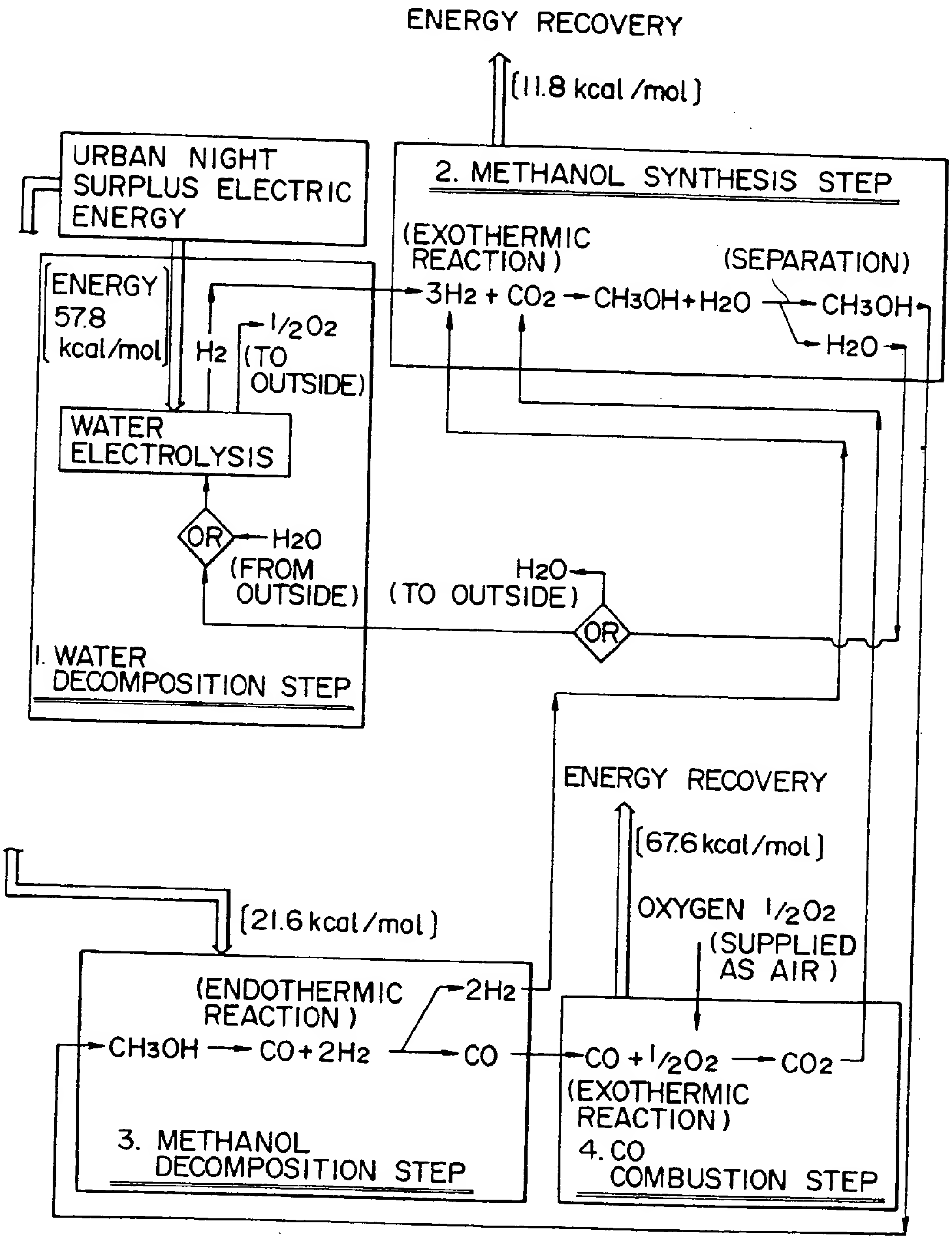
X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

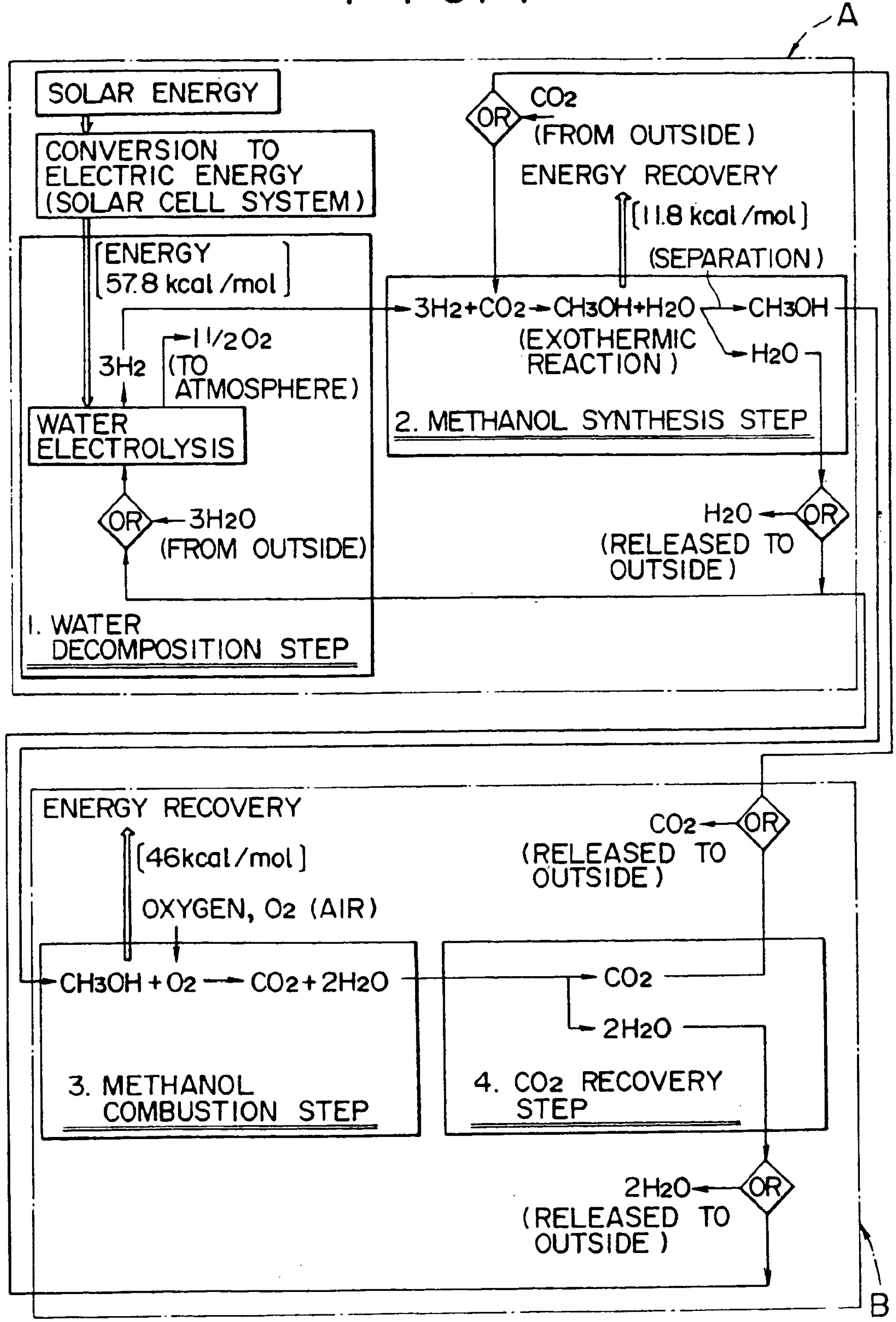
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P0401)

F I G. 2


ENERGY RECOVERY
(11.8 kcal/mol)
URBAN NIGHT SURPLUS ELECTRIC ENERGY
2. METHANOL SYNTHESIS STEP
(EXOTHERMIC REACTION)
(SEPARATION)
3H2 + CO2 → CH3OH+H2O
CH3OH
H2O
ENERGY 57.8 kcal/mol
H2
1/2O2 (TO OUTSIDE)
WATER ELECTROLYSIS
OR
H2O (FROM OUTSIDE)
H2O (TO OUTSIDE)
OR
1. WATER DECOMPOSITION STEP
ENERGY RECOVERY
(67.6 kcal/mol)
OXYGEN 1/2O2
(SUPPLIED AS AIR)
(21.6 kcal/mol)
(ENDOTHERMIC REACTION)
2H2
CH3OH → CO+2H2
CO
CO + 1/2O2 → CO2
(EXOTHERMIC REACTION)
3. METHANOL DECOMPOSITION STEP
4. CO COMBUSTION STEP

F I G. 1


A
SOLAR ENERGY
CONVERSION TO ELECTRIC ENERGY (SOLAR CELL SYSTEM)
[ENERGY 57.8 kcal/mol]
3H2
1 1/2 O2 (TO ATMOSPHERE)
WATER ELECTROLYSIS
OR
3H2O (FROM OUTSIDE)
1. WATER DECOMPOSITION STEP
OR
CO2 (FROM OUTSIDE)
ENERGY RECOVERY
[11.8 kcal/mol]
(SEPARATION)
3H2+CO2→CH3OH+H2O
CH3OH
H2O
(EXOTHERMIC REACTION)
2. METHANOL SYNTHESIS STEP
H2O
OR
(RELEASED TO OUTSIDE)
ENERGY RECOVERY
[46kcal/mol]
OXYGEN, O2 (AIR)
CH3OH + O2 → CO2 + 2H2O
3. METHANOL COMBUSTION STEP
CO2
OR
(RELEASED TO OUTSIDE)
CO2
2H2O
4. CO2 RECOVERY STEP
2H2O
OR
(RELEASED TO OUTSIDE)
B

thanol synthesis in which methanol is synthesized from carbon dioxide recovered in a subsequent carbon monoxide combustion step and from the hydrogen obtained in the water decomposition step and also in a subsequent methanol decomposition step and then the synthesized methanol is separated from secondarily produced water; methanol decomposition in which the methanol that has been synthesized in the methanol synthesis step is decomposed into carbon monoxide and hydrogen by the energy from a given energy source; and carbon monoxide combustion in which the carbon monoxide that has been obtained in the methanol decomposition step is burned to give energy, while the carbon dioxide thereby produced is recovered.